SCHOFIELD BARRACKS MILITARY RESERVATION, KU TREE RESERVOIR, VALVE TOWER — **HAER No. HI-81-B**

Kalakoa Stream
East Range
Wahiawa Vicinity
Honolulu County
Hawaii

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Department of the Interior
1849 C Street, NW
Washington, D.C.

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Location:	Kalakoa Stream (Tributary to the South Fork of Kaukonahua Stream) Approximately 3 miles east of Wahiawa East Range, Schofield Barracks Military Reservation Wahiawa Vicinity City and County of Honolulu Hawaii USGS 7.5 minute series topographic map, Waipahu, HI 1998 Universal Transverse Mercator (UTM) coordinates: 04.605680.2377540
Date of Construction:	1922-1925
Engineers & Builders:	Office of the Quartermaster General and Office of Chief of the Fourth Construction District
Present Owner:	U.S. Army
Present Occupant:	U.S. Army (training area)
Present Use:	Reservoir drained and abandoned, valve tower's operating room not extant.
Significance:	The valve tower is significant as an element of the Ku Tree Reservoir and as a rare example of a masonry valve tower constructed in Hawaii in the 1920s. The structure is typical of its period in its use of materials, method of construction, craftsmanship, and design. Because of their relatively small scale, very few reservoirs in Hawaii employ valve towers. Thus, Ku Tree's tower is one of the few examples of this type of structure in the islands.
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Date:	June 2008

For additional information see the main report on the Ku Tree Reservoir (HAER No. HI-81), as well as the individual reports on the other related structures in this complex (HAER Nos. HI-81-A, HI-81-C, and HI-81-D).

DESCRIPTION:

Valve towers are watertight, hollow, vertical masonry chambers, which allow water to be drawn from a reservoir. Typically located near the toe of the inner slope of a dam, a valve tower rises from the bottom of the reservoir, through the reservoir waters, to above the surface. An enclosed operating room is built on a platform at the top of the tower to protect the mechanisms that operate the various intake and discharge valves that regulate the flow of water out of the reservoir. A footbridge usually provides access to the tower from the shore. Almost half the sheets of the drawing set for the Ku Tree Reservoir are for the details of the valve tower.

The Ku Tree Reservoir's valve tower is hexagonal in plan and built of reinforced concrete. It is sited at a 52-degree angle from the axis of the dam, and about 260' from the dam crest along that line. At its base the width of the tower is 29'-5½" (measured between parallel faces) or 34'-0" (measured corner to corner). Its height is 102'-0", measured to its reinforced-concrete service platform. At the base, each face of the hexagonal tower is 17'-0" wide. The main shaft width is 13'-0" (measured between parallel faces) from elevation 1030' to the top, but the bottom 30'-0" of the main shaft has walls 2'-6" thick, while the wall thickness of the top 25'-0" is 2'-0", around a wider hexagonal well. Ribs, or buttresses, measuring 2'-0" thick, project approximately 2' from each of the six corners of the hexagonal shaft. The diameter of the tower (from elevation 1030' to the top), including ribs, is generally 20'-0". The ribs flare out at the top to create supporting brackets for the operating room platform. The ribs near the bottom, from elevation 1000' to 1030', taper from a projection of about 6' to the 2' dimension on the upper part of the tower. Additional tapered buttresses support the tower below elevation 1000'. A lateral face of one of the ribs on the tower's east side features a gauge with numerals, each measuring 2'-0" high and 8" wide, incised in the concrete. Numbered in ten-foot increments with intervening one-foot hash marks, the gauge indicated the water level within the reservoir. The front face of another rib has 1¼"-diameter metal ladder rungs embedded in it, from the 993-foot elevation to the top.

The original drawings and historic photographs show that a wood-frame operating room, which is not extant, stood on top of the service platform, which measures 21'-6" between parallel sides. The operating room sheltered the controls for the nine sluice gates that managed the flow of water into and out of the tower. The hexagonal-plan operating room had a 1/1 double-hung sash window in each of its walls, and doorways on two sides (for access via boat or bridge). Photos in a 1983 report show that the wood-stud framing was exposed on the interior and the exterior had vertical tongue-and-groove siding with textured paint (Walter Lum Associates, Inc. 1983: A-3 & A-20). The structure was capped by a hipped hexagonal roof with overhanging eaves and exposed rafter tails. At the center of the room a pipe railing surrounded a grate-covered well opening in the operating-room floor. The various valve and gate controls were located around the sides of the well.

This hexagonal-plan inner well measures 7'-0" (lower 30' of shaft) or 8'-0" (upper 25' of shaft) in width between parallel walls. Water used to flow from the reservoir into the tower's well through five 18" x 24" sluice gates. These gated intakes for the well are located on various exterior faces of the tower at invert elevations of 1065', 1050', 1035', 1020' and 1005'. Concrete service platforms, approximately 4' wide, are located above each sluice gate. Metal ladder rungs, 1¼"-diameter, imbedded in the walls of the well provided access to each platform. The rungs, especially near the top, have been compromised by rust and corrosion. The sluice gates could be manually operated, with vertical slide mechanisms, but these are missing or inoperable due to rust. Each gate had a protective trash screen.

Two tunnels connected to the base of the tower transported the water to desired locations on the downstream side of the dam. The drain tunnel returned waters from the reservoir back into the Kalakoa Stream on the downstream side of the dam. This tunnel still carries the flow of the stream under the dam embankment. The 6'-0" wide and equally high concrete-lined tunnel is approximately 515' long. The initial 15' of the drain tunnel (closest to the valve tower) has a gable-shaped ceiling which rises from straight walls 5'-0" high, while the ceiling of the remainder is segmental arched, springing from 4'-6"-high straight walls. The first 100' of the drain tunnel from the tower is sloped at approximately six percent, the following 160' at four percent, and the remainder of the tunnel at one percent (Walter Lum Associates, Inc., 1983, 17). The reinforced-concrete lining in the tunnel for the first 15' is 2'-0" thick, while the remainder is at least 6" thick. The drain tunnel runs under the dam discharging drained waters from the valve tower to the downstream section of the Kalakoa Stream at elevation 980'. The smooth concrete face of the tunnel on the downstream side has the date 1923 imprinted above its segmental-arched opening.

The discharge tunnel and its pipe took the reservoir waters to the end users. The partially lined discharge tunnel, measuring approximately 5' wide and a little more than 6' tall, holds a 24"-diameter cast-iron pipe. Its tunnel number 1 runs approximately 1300', with a portion going under the upper end of the spillway. The pipe in tunnel number 1 connected with a 20"-diameter cast-iron pipe that ran 1,600' in tunnel number 2 before joining with an 18"-diameter cast-iron pipe from the Koolau Reservoir, to feed a 24"-diameter cast-iron pipe that ran to urban core of Schofield Barracks.

Portal No. 6 is located on the east bank of the Kalakoa Stream downstream of the spillway, at the point where the stream bends to the west. This partially lined tunnel, with its concrete floor and rock walls, runs approximately 125' into the mountain, providing access to the junction of tunnels 1 and 2 of the discharge pipe. The portal has a round-arched opening and a concrete floor with a walkway on the right side. The walls of this access tunnel are carved out of the stone. The sides of the portal are grooved at its opening, indicating it may have had a gated entry at one point.

An engineering report (Walter Lum & Associates, Inc., 1983: 11) noted that, when functional, the flow from the Ku Tree Reservoir valve tower could go two ways:

1. through a 24" x 24" sluice gate into a 24"-diameter cast-iron pipe in the discharge tunnel, which fed into the Schofield Barracks' water distribution system, or
2. water would flow into the tower through two 36" x 72" sluice gates at Invert Elevation 995', then out, into the drain tunnel, through a 36" x 72" sluice gate at Invert Elevation 992'.

The drain tunnel runs under the dam and, since the reservoir was drained, has been the route for passing the water back into Kalakoa Stream below Ku Tree dam.

All sluice gates have vertical stems extending up to floor stands mounted on the operating platform. The control gate valves are now closed and rusted. When they were operational, the maximum capacity of the outlet works was 619 cubic feet per second.

The valve tower retains its integrity, as there have been no alterations or additions made to it. However, since the drawing down of the reservoir in 1983 it has deteriorated. Its operating room has collapsed, with some of its debris still remaining on the platform. The tower's mechanisms have rusted, and a number of the sluice gates are missing. In 1983 when the Ku Tree Reservoir was drawn down, the drain tunnel sluice gates were left in the open position, and water from the reservoir side of the dam continues to pass through the drain tunnel to rejoin the Kalakoa Stream on the downslope side. The discharge tunnel and pipe are no longer functional.

HISTORICAL CONTEXT

Reservoir valve towers built of masonry came into use in Europe during the mid-nineteenth century. The valve tower served as the outlet works for the reservoir, releasing and regulating the waters impounded by the dam. Outlet works were designed to release specific amounts of water, as dictated by downstream needs, including flood control regulation, and storage requirements for irrigation and drinking water.

The other option for discharging waters from reservoirs was to use pipes embedded in the dams, with their flow controlled by a valve house on the downstream side of the dam. The 1919 Koolau Dam is an example of a small dam with a valve house on the downstream side of the dam. Problems inherent in the downstream valve house approach included the placement of stressful pressures on pipes whenever the water flow through larger dams was stopped; also repairs were difficult, if a pipe should burst or spring a leak. Masonry valve towers, although expensive to construct, successfully eliminated these problems by placing the outlet works on the upstream side of the dam. Another advantage of the valve tower was that it allowed water to be drawn from near the surface of the reservoir where it was least turbid and discolored, providing a better-quality water to the end user. In addition, usually one intake was placed sufficiently low on the tower to draw the reservoir down to the bottom if necessary.

Masonry valve towers that stand independent of the dam were usually associated with earth-fill dams. Masonry dams frequently incorporated valve towers or shafts into the dam structure itself, as the structural integrity of the masonry dam was less threatened by seepage.

Because of the size of the Ku Tree Reservoir and its dam, an intake tower was planned from the start, as shown in the 1919 contour map of the overall reservoir (Sheets 2 and 3 of the reservoir's original drawings). After Congress appropriated the necessary funds to construct the reservoir in 1921, more detailed drawings were prepared. The two 1919 sheets and five 1923 drawings (sheets 1, 26-28, and 33) display the title block of the Office of the Constructing Quartermaster, Honolulu, T.H. The title blocks for the other original drawings of the reservoir indicate they were done by staff in the Office of Chief of the Fourth Construction District, Honolulu. Unfortunately the names of the designers are not known and typically only initials are shown on the drawings. The plans for the outlet tunnels were drawn by Johnson in February 1923. The details for the valve tower's gates and screens were completed in March 1923 by Harrison. Because of these early 1923 dates, done before the particulars of the Ku Tree valve tower were finalized, they were probably based on standard designs for such elements. This may also be the case with the drawings by G.N. dated November and December 1923, which show additional details of valve tower gates. The final plans for the valve tower, also with the initials G.N., were dated between June and November of 1924.

In addition to the Ku Tree Reservoir valve tower, other known valve towers in Hawaii include those at Lake Wilson in Wahiawa and at Nuuanu 4 Reservoir in Honolulu. The tower at Lake Wilson is approximately 40' in height, while the one in Nuuanu, which was constructed in 1933-34, is about 70' tall.

The Ku Tree Reservoir's valve tower's design, method of construction, and material were typical of its time. It was constructed of reinforced concrete, which by the 1920s was an accepted building material for industrial buildings, bridges, and other utilitarian structures. American engineer Thaddeus Hyatt published his ground-breaking book, *An Account of Some Experiments with Portland Cement Concrete, Combined with Iron, as a Building Material*, in 1877; however, reinforced concrete did not begin to gain acceptance as a building material until the last decade of the nineteenth century, with Ernest Ransome being a pioneer in the field. By the late 1890s, reinforced concrete was used in the United States to build grain elevators and storage tanks as well as factories and industrial buildings. In 1903 the fifteen-story Ingalls Building in Cincinnati became the first skyscraper to be constructed out of reinforced concrete. Until that time, no reinforced concrete structure had gone more than six stories, as engineers, familiar with ordinary concrete's low tensile strength, feared wind loads would collapse taller structures, despite the metal reinforcing bars.

Concrete was first used as the main structural material of dams in 1904; however, it had been used in valve towers even earlier. Two picturesque examples which survive to the present include the 170-foot-high Vyrnwy valve tower with its Gothic Revival-style operating room and bridge. Located in Wales, this reservoir's stone dam (Great Britain's first large-scale masonry dam) and concrete valve tower were constructed in the 1880s. In New Zealand the Karori Reservoir's valve tower (1873), with its High-Victorian-style operating room, included a concrete shaft (Wymer, n.d.: 2, and Vernon-Harcourt, 1907: 187-188).

The design of the Ku Tree valve tower was typical for its period. The placement of intake valves at different elevations and the use of two separate pipes, one for drainage and one for discharge, were common elements present in valve towers of the period. Also designing the tower as an independent structure placed away from the dam had become a standard practice by the 1920s for large earth-fill dams. The Ku Tree Reservoir tower's hexagonal-plan design with ribs at the corners was also an already established form. For instance, James Dix Schuyler's Sweetwater Reservoir near San Diego, California (1899) included a hexagonal-plan stone valve tower. The hexagonal shape allowed for a stable, quasi-circular form while providing flat surfaces to facilitate easy operation of the sluice gates (Schuyler, 1909: 220-223 and Wilson, 1910: 449-452).

The drain and discharge tunnels also followed standardized forms of the period. The second most common reason for the failure of earth-fill dams in the nineteenth century was the faulty laying of outlet pipes, with leakage from the pipes undermining the dam (see the spillway report, HAER No. HI-81-D, for the number-one reason for failures). On large dams the weight of the dam alone was sufficient to compromise the integrity, if not crush, any outlet pipes laid in the dam. To counter this problem, drain tunnels running through earth-fill dams were concrete-lined and of sufficient size to allow work crews to inspect and repair them. The drain tunnel running under the Ku Tree Reservoir's dam is concrete-lined and its 6'-0" width is sufficiently large to allow room for a repair crew. Similarly the discharge tunnel, which primarily runs through rock, has partial lining of concrete and was designed to be large enough to allow easy access to the pipe it protected.

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PROJECT INFORMATION

See main report for Ku Tree Reservoir, HAER No. HI-81.

Figure 1: Elevation and Section, Valve Tower, Ku Tree Reservoir. Job No. S3603, Sheet 11, dated Sept. 3, 1924.

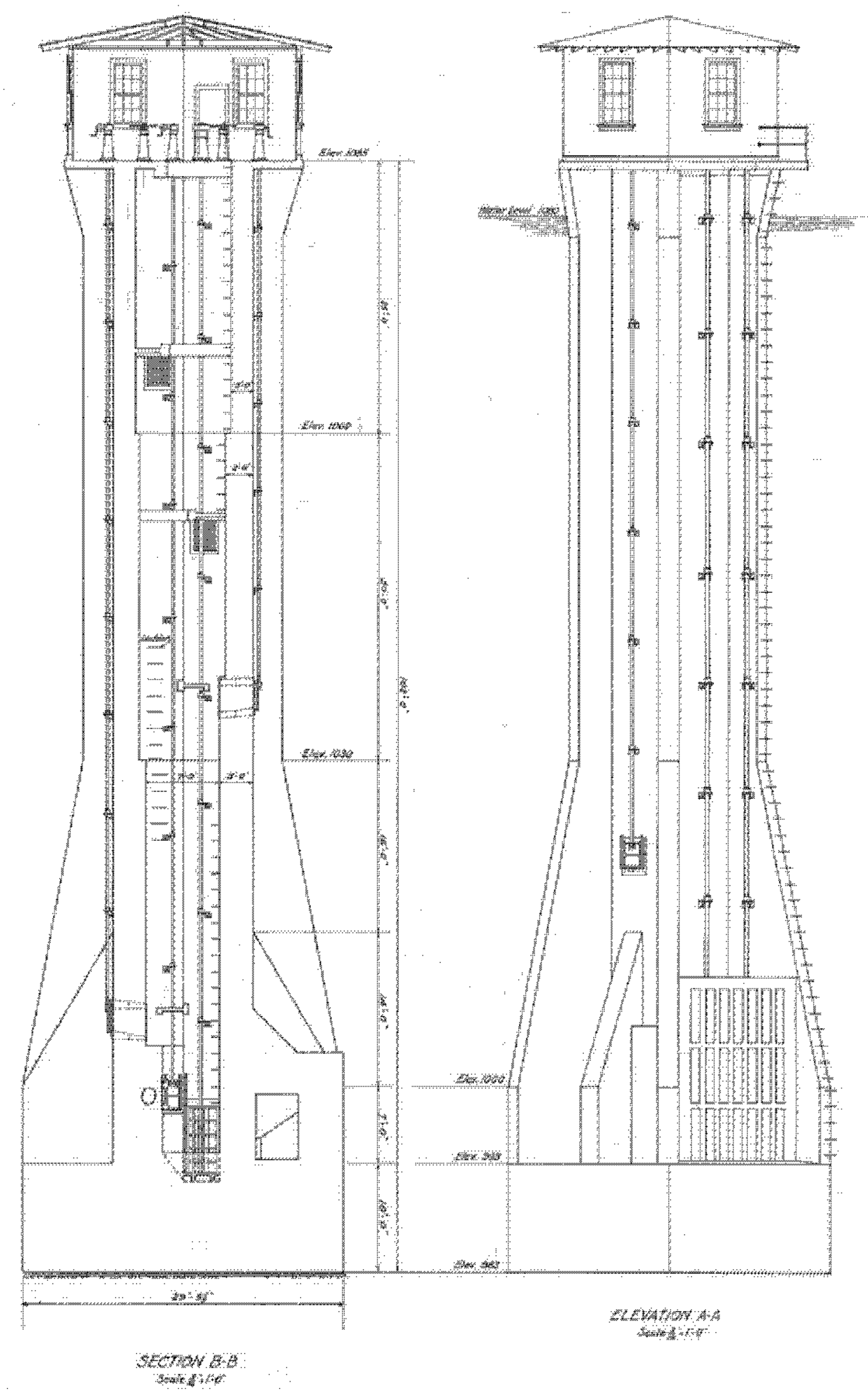
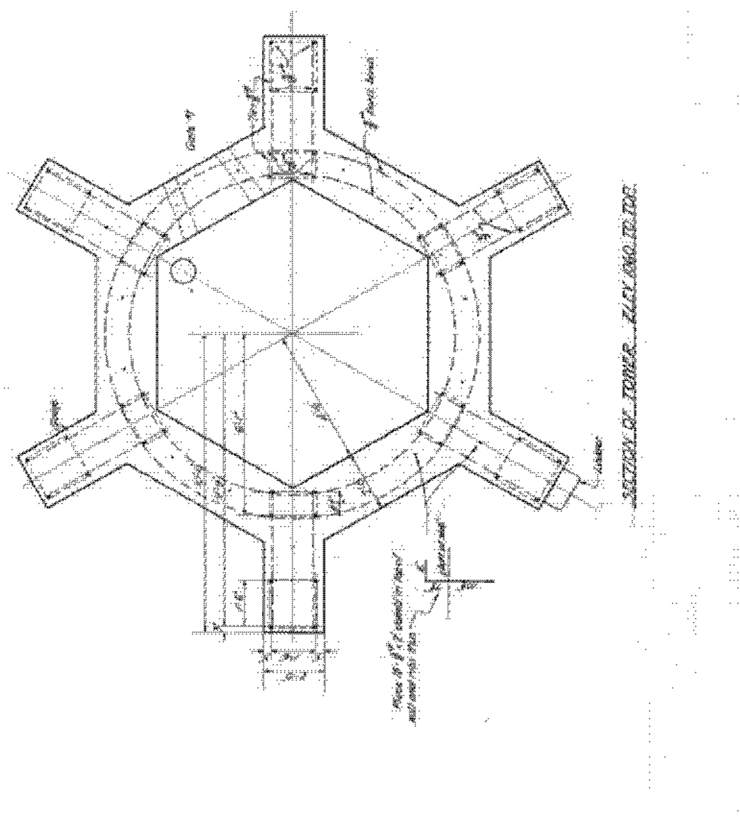


Figure 2: Valve Tower Details. Job No. S3603, Sheet 16, dated April 18, 1924.



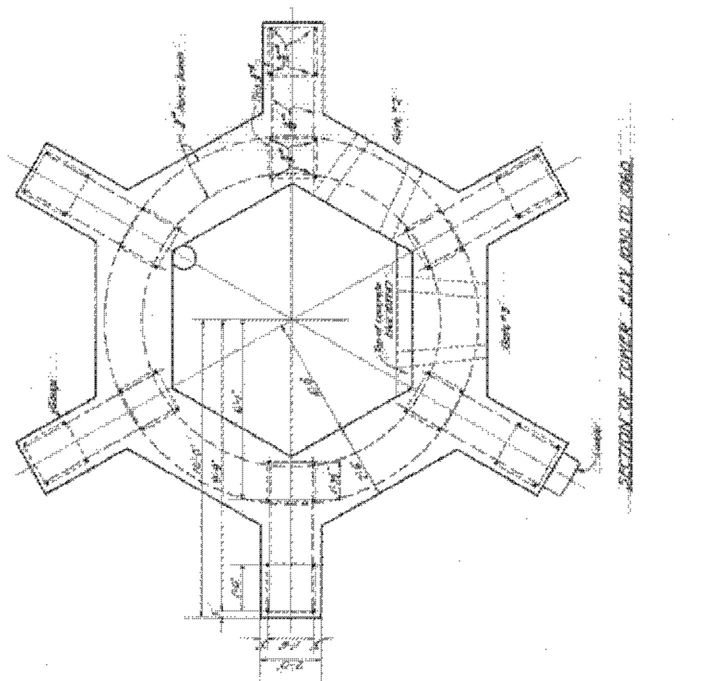


Figure 3: Gates for Valve Tower, Ku Tree Reservoir. Job No. S3603, Sheet 28, dated Dec. 1, 1923.

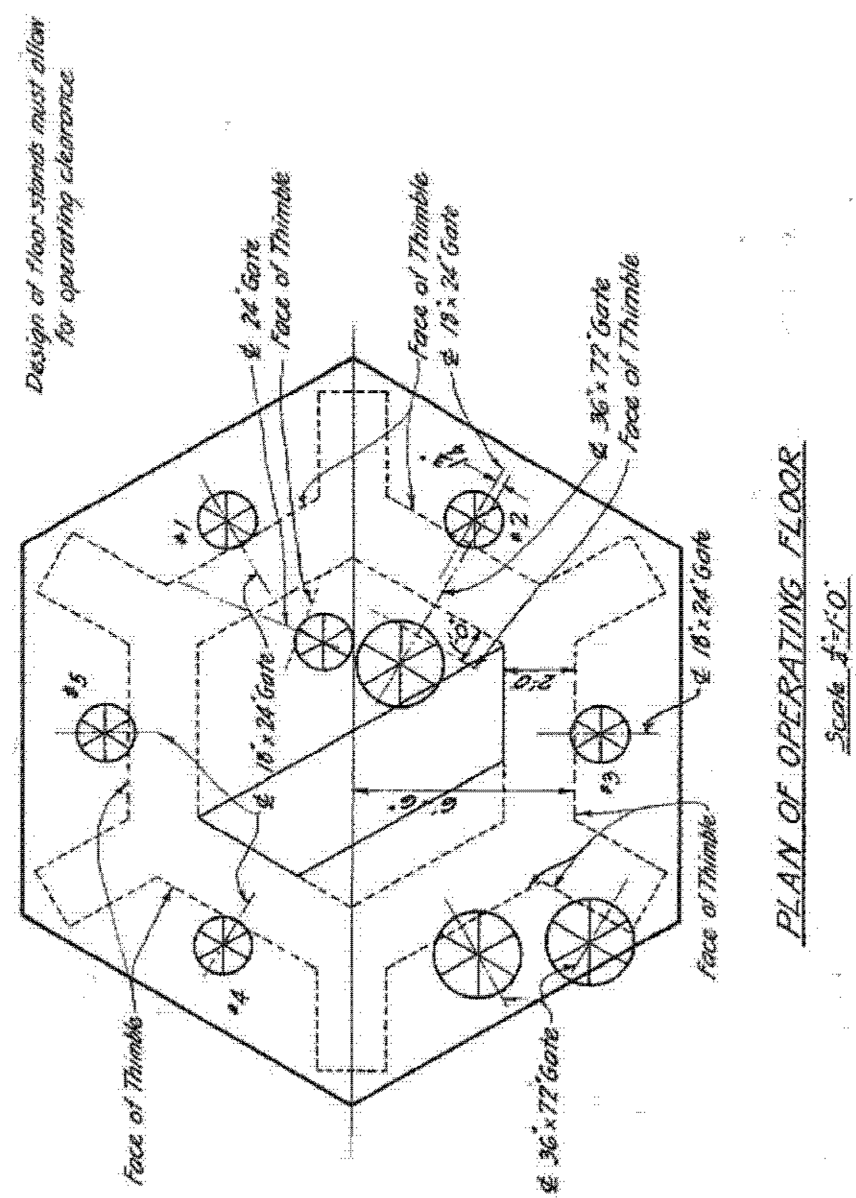


Figure 4: Valve tower, Ku Tree Dam, November 12, 1924. (Tropic Lightning Museum, Schofield Barracks, Hawaii, Historical photograph 87.76.01-27)

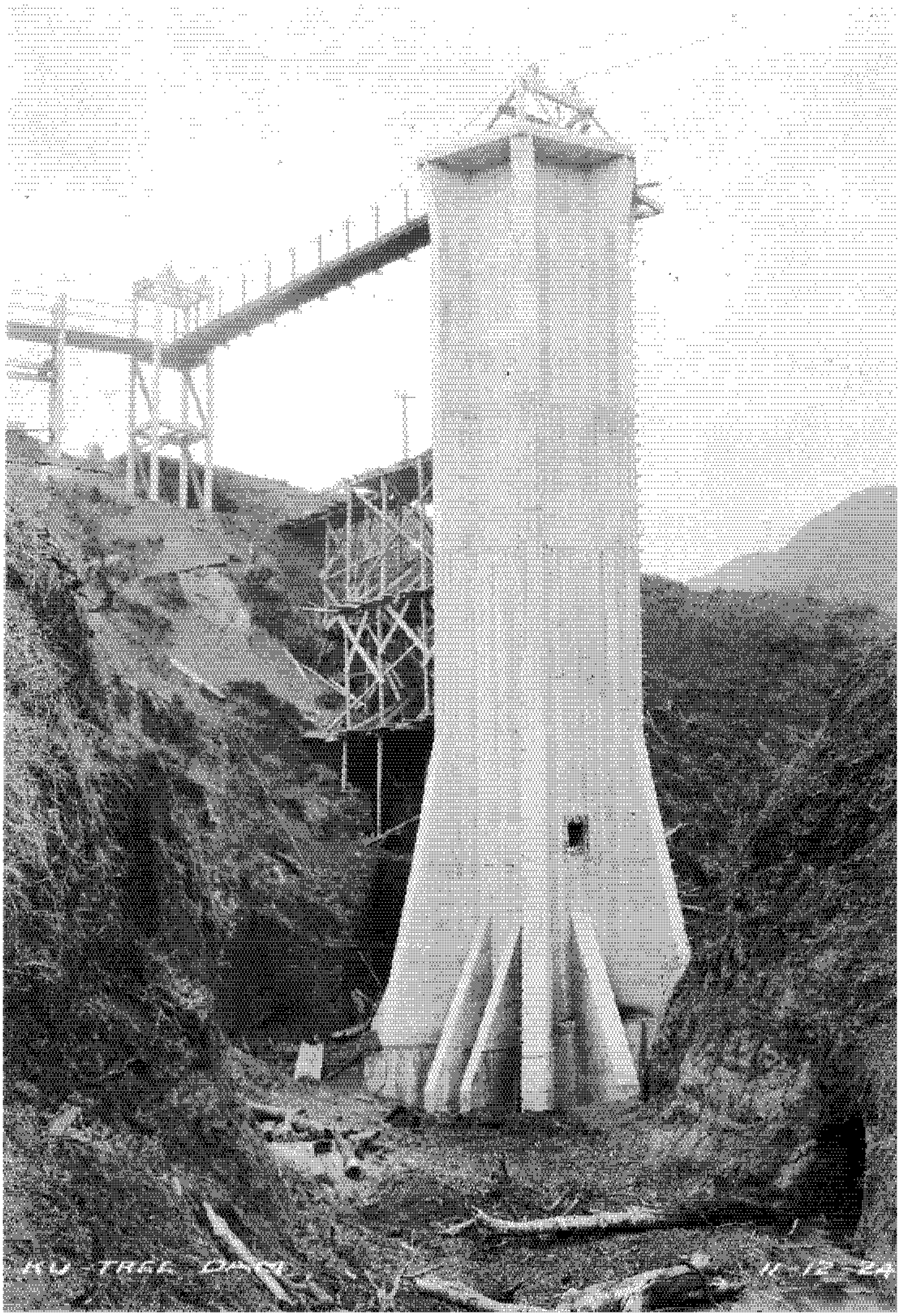


Figure 5: Enclosed valve house on tower with water in reservoir. (Tropic Lightning Museum, Schofield Barrracks, Hawaii, Historical photograph 87.76.01-8)